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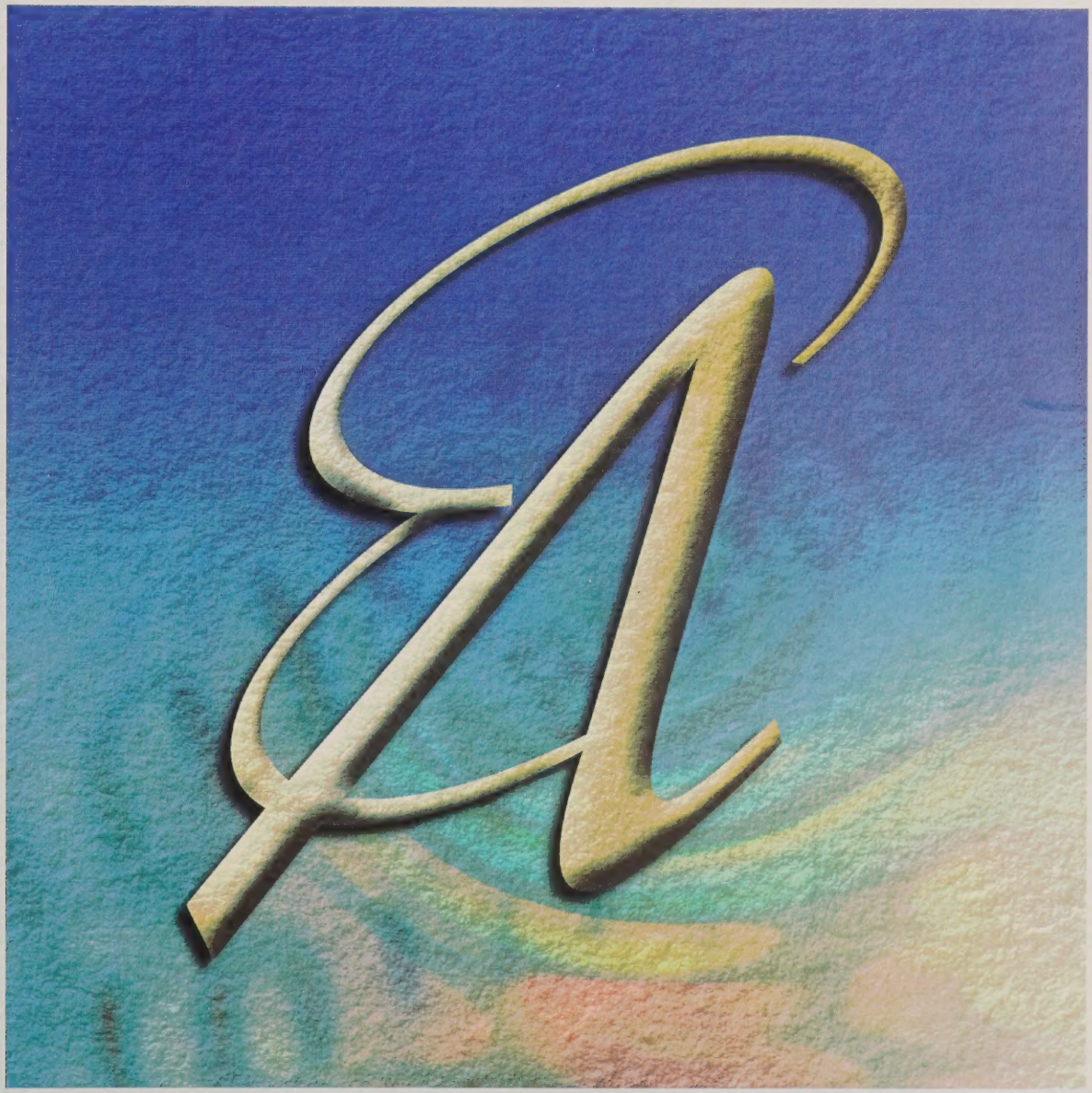
*A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communication Technologies*

**by Philip Armstrong, Tarek M. Harchaoui, Chris Jackson and Faouzi Tarkhani**

**No. 001**



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# A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communication Technologies†

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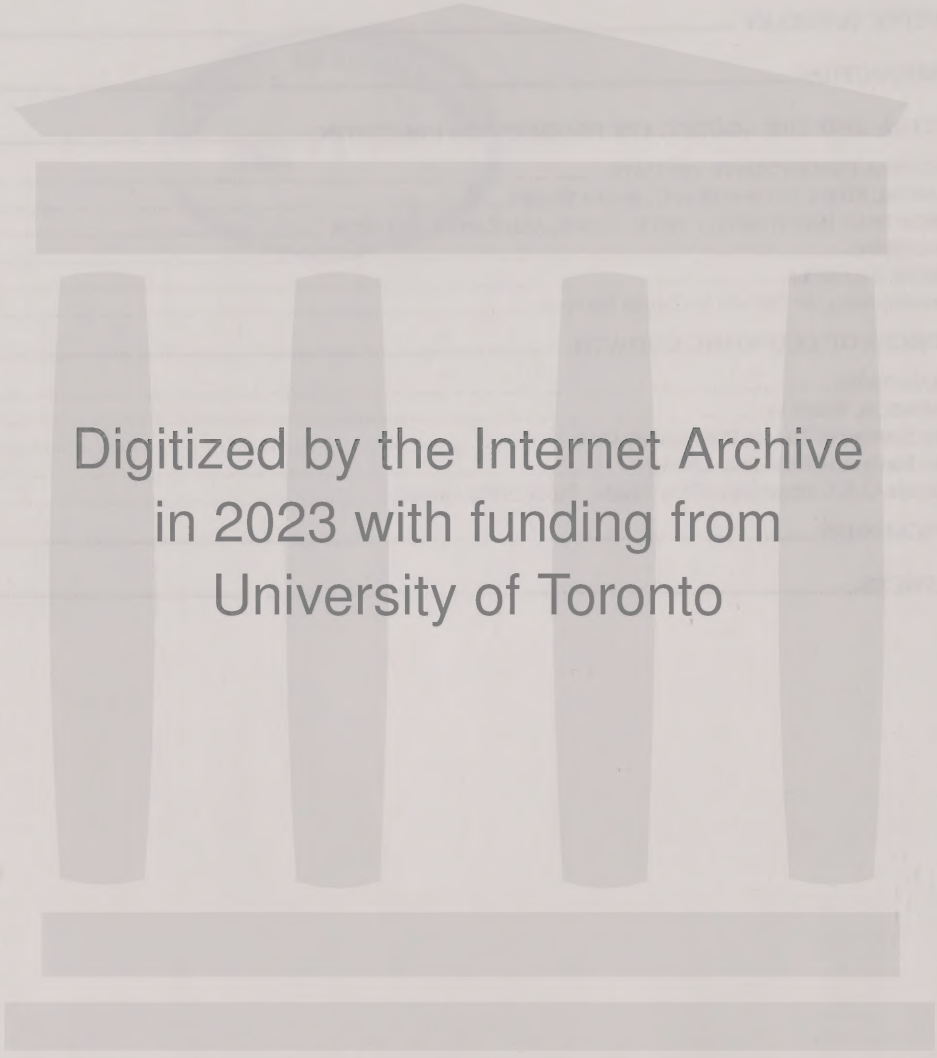
The opinions expressed herein are those of the authors and do not necessarily reflect the opinions of Statistics Canada.

*Aussi disponible en français*

† The comments that were made by John R. Baldwin and Wulong Gu are acknowledged with thanks. Note that preliminary GDP data from 1998 onward are used in this analysis.

# *Table of Contents*



## *Abstract*

Using revised Statistics Canada estimates of output and inputs, this paper examines changes in the patterns of capital formation and the sources of economic growth for the Canadian business sector over the 1995-2000 period and makes comparisons with the 1981-1995 period.

The changing composition of investment and the growth of capital services across broad asset classes is explored first. Then the growth in output is decomposed into components coming from growth in labour, capital and multifactor productivity. Finally, the extent to which information and communication technologies have made a key contribution to economic growth is investigated. Comparisons are made of the performance of the Canadian and U.S. business sectors in each of these areas.

The results confirm some already familiar patterns, but also some novel features, particularly for the 1995-2000 period. The data show that increases in capital and labour continue to be important contributors to output growth. The increase in the growth rate of investment during the 1995-2000 period, which has occurred across many asset classes, has led to an increased growth contribution of capital services to output growth. A considerable increase in the number of hours worked has also contributed to economic growth; the substantial growth in labour inputs has muted the capital deepening effects of the rapid increase in capital services. The third primary source of growth in output, multifactor productivity growth, was 1.0% on average during the post-1995 period in Canada and 1.3% in the U.S. This increase was considerably higher than in the 1980s and early 1990s, especially in Canada. Although the resurgence in multifactor productivity in both countries does not surpass the pre-1973 performance, it was one of the most important stylized facts of the last five years of the twentieth century.



***Keywords:*** growth accounting; new economy

## *Executive Summary*

Over the last two decades Canadian business investment in information and communication technology (ICT), defined here to include purchases of computer hardware, computer software, and telecommunications equipment, grew at 16.2% on average. The rate of growth in ICT was higher than in most other asset classes. In 2000 alone, these assets accounted for 6.4% of the $1.3 trillion dollars of total fixed capital, up from 3.9% in 1981.

Canadian businesses have been making a major commitment to ICT, presumably in the hope of improving their performance and profitability. This steady adoption of ICT reflects the unprecedented decline in the relative price of computing power and the explosion of ICT capability—measured in terms of processing speed, memory, transmission capacity, and storage space. The quality-adjusted price of ICT, which measures the price of a fixed amount of ICT power, has fallen 9.3% per year since 1981.

Relative price declines like these are familiar to technologists and economists alike, and reflect the fundamental technical progress in the production of computers, semiconductors, and other high-tech gear. This has lead directly to the rapid accumulation of ICT investment goods as firms have responded to relative price changes, substituted between production inputs, and invested heavily in ICT assets that are much cheaper now than in the past. As a result, growth rates of ICT have outpaced those of other investment assets and Gross Domestic Product (GDP).

What are the impacts of this technological progress and the accumulation of ICT assets on the Canadian business sector? How does the Canadian business sector compare with its U.S. counterpart? This paper addresses these questions with a new set of productivity estimates.

Business sector output grew 3.3% on average over the 1981-1988 period: of this, capital input contributed 1.4%—0.6% as a result of the changing composition of assets (asset quality) and 0.8% as a result of increases in total capital; labour input contributed 1.7%—0.5% as a result of the changing composition of labour inputs (labour quality) and 1.2% from an increase in total hours. The size of the relative contributions of labour and capital is somewhat similar to the 1995-2000 period, when labour input at 2.2% also contributed more than capital input (1.7%) to output growth.

What is even more remarkable about the post-1995 period, compared to the previous periods, is the resurgence in multifactor productivity performance in Canada and the U.S. (an average annual rate of 1.0% for Canada and 1.3% for the U.S. compared to 0.2% and 1.0%, respectively, for the 1981-1988 period). The increase in multifactor productivity was much higher in Canada than in the U.S. This acceleration in multifactor productivity growth suggests considerable improvements in technology and increases in the efficiency of production in both countries.

# *I. Introduction*

Information and communication technology (ICT) equipment appears to be almost everywhere—on the desks of executives, on the factory floor, in the classroom, at home, and, these days, even in people's pockets. By all accounts, ICT appears to be rapidly changing the way many enterprises conduct business and communicate. The proliferation of ICT has made the world seem much smaller, as computer-related innovations, such as the Internet, let individuals on opposite sides of the world interact in ways that were unimagined 20 years ago.

The explosion of ICT spending over the last few decades has sparked renewed interest in the role of investment and capital accumulation as sources of economic growth. While productivity growth, capital accumulation, and the impact of technology were topics once reserved for academic debates, the recent success of the U.S. economy has moved them into the popular domain (see Jorgenson and Stiroh, 2000; see also Khan and Santos, 2002 for a Canada-U.S. comparison).

Using revised data on output and capital input, this paper sheds some new light on the changing composition of investment and the growth of capital services in Canada during the 1990s and makes comparisons to the 1980s. In particular, well-tested and familiar methods are employed to estimate annual indices of capital services for the Canadian business sector from 1981 to 2000 and a decomposition into quantity and quality components for broad asset classes, including ICT equipment, is introduced. While much of the recent Canadian economic literature has documented the growing importance of computers, the extent to which ICT and other types of capital have contributed to economic growth in Canada are examined and compared. As a by-product, the underpinnings of the productivity performance of the Canadian and U.S. business sectors over the last two decades are examined using comparable methodologies.

Our approach distinguishes between *capital quantity* growth due to investment, and compositional change of asset types (sometimes referred to as *capital quality* growth) due to substitution between different types of capital assets. Much of the recent investment boom reflects substitution towards high-tech assets as their relative price steadily fell. Quantity and quality decompositions for broad asset classes, such as ICT, other machinery and equipment (made of low-tech equipment), and various types of structures are also introduced.

Our primary conclusion is that the Canadian business sector has experienced a steady and pervasive increase in the growth rate of capital services during the second half of the 1990s. The growth of capital services—including fixed reproducible capital, land, and inventories—has increased from an average annual growth rate of 3.5% for 1981-1988 to 4.2% for 1995-2000.

When sources of Canadian economic growth in output from 1995 to 2000 are examined, the data show that capital and labour continue to make important contributions to overall growth. The increase in the growth of investment, from 1.7% per year over 1981-1988 to 11.9% over 1995-2000, has led to an increase in the contribution of capital services from 1.4% to 1.7% per year between these two periods. Due to strong investment and an increasing input share, high-tech

equipment is the only class of fixed reproducible assets that is making a significantly larger contribution to output growth in the second half of the 1990s relative to the 1980s.

During the post-1995 period, the growth contribution of labour input has advanced primarily as a result of the increase in hours worked. The contribution of labour quality declined, a reflection of a falling unemployment rate as more workers with relatively lower marginal products were drawn into the workforce during this period.

The third primary source of growth, multifactor productivity or the famous Solow residual, grew at 0.2% per year on average during the last two decades in Canada, compared to 0.9% per year for the U.S. The acceleration of multifactor productivity in Canada from -0.3% per year over 1988-1995 to 1.0% per year during the post-1995 period (0.5% to 1.3% in the U.S.) suggests considerable improvements in technology and increases in the efficiency of production. While the resurgence in multifactor productivity growth in the post-1995 period has yet to surpass the pre-1973 performance, more rapid multifactor productivity growth is critical for sustained growth at higher rates.

During the post-1995 period, multifactor productivity contributed 21% of the output growth in Canada (27% for the U.S.), up from 6.1% in the 1981-1988 period (26% for the U.S.). Although the recent resurgence in multifactor productivity in both countries does not surpass the pre-1973 performance, it is certainly one of the most important stylized facts of the end of the twentieth century.

The remainder of the paper is organized as follows: Section II discusses the data sources and the historical trends of investment and capital formation. Section III analyzes the impacts of these trends on labour productivity and multifactor productivity performance. Section IV concludes the paper.

## *II. Capital and the Aggregate Production Function*

### *1. General Description of the Data*

This paper is based on methodologies recently implemented by the productivity program at Statistics Canada that constructs new Fisher indices of output and inputs for the Canadian business sector that are then used to construct multifactor productivity estimates.

The Fisher output indices use the expenditure based GDP estimates released in the Income and Expenditure Accounts on May 31, 2001, but exclude out-of-scope components such as the government sector, non-profit institutions and the rental on owner-occupied dwellings. Corresponding adjustments are also made to capital stock and hours worked. The GDP estimates incorporate the capitalization of software expenditures making the Canada-U.S. estimates of economic growth comparable for the first time since October 1999 when the U.S. Bureau of Economic Analysis introduced this change during a comprehensive historical revision to their National Income and Product Accounts.

Statistics Canada's new methodology for estimating the growth of capital services that is appropriate for an aggregate production function analysis is outlined in Harchaoui and Tarkhani (2002). The estimation procedure begins with estimates of real investment flows by detailed asset class, then calculates capital stock for each asset class by industry using the perpetual inventory technique. It then estimates the user cost of capital for each industry using Input-Output Tables to derive rates of return at the industry level, micro-economic price data on over 30,000 sales of used assets to obtain depreciation rates (Gellatly, Tanguay and Yan, 2002) and detailed information on tax rates. The growth rates of the stock of capital by asset type of individual industries are then aggregated using the user cost of capital to derive an estimate of the growth in the flow of capital services by industry.

For the analysis in this paper, the wide number of assets used in the productivity program (28 classes) are grouped into three distinct classes. Table 1 shows the concordance that produces three broad asset classes—ICT, other machinery and equipment, and structures (which includes inventories and land).[1] This taxonomy not only distinguishes long-lived structures from short-lived equipment, but also information and communications technologies (ICT) from other machinery and equipment.

This paper also uses estimates of labour growth that take into account differences in marginal productivity across labour types (see Gu, Kaci, Maynard, and Sillamaa, 2002). Contrary to the method that just sums all hours-worked across all workers, the method that considers differences across labour types sums the growth in hours-worked of different classes of labour weighted by their relative wage rates or their share of labour compensation. Much like the estimates of capital input that capture substitution across asset classes, the approach developed by Jorgenson, Gollop and Fraumeni (1987) for aggregate labour input allows for substitution between various types of labour, e.g., workers cross-classified by education, experience, and other characteristics. This approach allows for a breakdown of the growth of labour input into growth of labour hours and a labour composition or labour quality effect that is similar to the breakdown in capital growth between the straight sum of all capital and changes in its composition.

[1] The definition of information and communications technologies (ICT) assets, which includes computer hardware, software and telecommunication equipment, is chosen to permit comparisons with the U.S. (see U.S. Bureau of Labor Statistics 2000). There are currently efforts underway within the OECD to define a broader set of ICT commodities which include not only the investment assets used in our definition but also intermediate goods and services, and final demand categories.

**Table 1. Classification of Total Capital by Asset Class**

| |
|---|
| **Information and Communication Technology** |
| Computers and Office Equipment |
| Communication Equipment |
| Software-Own Account |
| Software-Pre-Packaged |
| Software-Custom Design |
| **Other Machinery and Equipment** |
| Office Furniture, Furnishing |
| Household and Services Machinery and Equipment |
| Electrical Industrial Machinery and Equipment |
| Non-Electrical Industrial Machinery and Equipment |
| Industrial Containers |
| Conveyors and Industrial Trucks |
| Automobiles and Buses |
| Trucks (Excluding Industrial Trucks) and Trailers |
| Locomotives, Ships and Boats and Major Replacement Parts |
| Aircraft, Aircraft Engines and Other Major Replacement Parts |
| Other Equipment |
| **Structures** |
| Non-Residential Building Construction |
| Road, Highway and Airport Runway Construction |
| Gas and Oil Facility Construction |
| Electric Power, Dams and Irrigation Construction |
| Railway and Telecommunications Construction |
| Other Engineering Construction |
| Cottages |
| Mobile Homes |
| Multiple Dwellings |
| Single Dwellings |
| Inventories |
| Land |

## *2. Capital Stock Estimates in Current Prices*

Table 2 contains a breakdown of assets into major groupings and the 1981 and 2000 value of capital stock by asset class. The perpetual inventory calculations result in a net stock of fixed reproducible assets of $929 billion in current dollars in 2000, up from $290 billion in 1981. Adding in the estimated value of land and inventories yields a total capital stock of $1.3 trillion in 2000.

**Table 2. Estimates of Depreciation and Capital Stock by Asset Class: Canadian Business Sector**
(millions of current dollars)

| | 1981 Capital Stock | | | 2000 Capital Stock | | |
|---|---|---|---|---|---|---|
| | Value $ | Fixed Capital Share (%) | Total Capital Share (%) | Value $ | Fixed Capital Share (%) | Total Capital Share (%) |
| Total Capital Stock | 492,588 | | 100.0 | 1,278,237 | | 100.0 |
| Fixed Reproducible Capital | 290,465 | 100.0 | | 929,409 | 100.0 | |
| Information, Communication and Technology | 11,363 | 3.9 | 2.3 | 59,900 | 6.4 | 4.7 |
| Computers and Software | 4,444 | 1.5 | 0.9 | 37,493 | 4.0 | 2.9 |
| Communication | 6,920 | 2.4 | 1.4 | 22,407 | 2.4 | 1.8 |
| Other Machinery and Equipment | 80,948 | 27.9 | 16.4 | 238,505 | 25.7 | 18.7 |
| Structures | 198,153 | 68.2 | 40.2 | 631,008 | 67.9 | 49.4 |
| Inventories and Land | 202,123 | | 41.0 | 348,828 | | 27.3 |
| Structures, Land and Inventories | 400,276 | | 81.3 | 979,832 | | 76.7 |

The investment in ICT in constant prices (see Table 3) has grown at an average annual rate of 16.2% during the 1981-2000 period, much faster than the other two classes of assets. Despite this rapid growth, however, ICT equipment remains a small share of the business sector's aggregate capital. In 2000, ICT capital stock in nominal terms accounted for 6.4% of fixed reproducible capital, which includes equipment and structures, up from 3.9% in 1981 (see Table 2). In our broader definition of capital stock that includes residential assets, land and inventories, ICT assets account for an even smaller share (4.7% in 2000 compared to 2.3% in 1981).

**Table 3. Average Annual Growth Rates of Investment, Capital Stock, Capital Services and Output: Canadian Business Sector**

| | Investment Index | | Capital Stock Index | | Capital Services Index | | GDP | |
|---|---|---|---|---|---|---|---|---|
| | Price | Quantity | Price | Quantity | Price | Quantity | Price | Quantity |
| | | | | 1981-2000 | | | | |
| GDP | - | - | - | - | - | - | 2.9 | 3.0 |
| All Assets | 1.0 | 3.6 | 1.0 | 2.0 | 4.2 | 3.4 | - | - |
| ICT | -9.3 | 16.2 | -9.3 | 12.7 | -1.5 | 21.0 | - | - |
| Other Machinery and Equipment | 2.5 | 2.0 | 2.5 | 2.1 | 5.6 | 3.4 | - | - |
| Structures | 1.5 | 0.8 | 1.5 | 1.7 | 6.8 | 2.1 | - | - |
| | | | | 1981-1988 | | | | |
| GDP | - | - | - | - | - | - | 4.5 | 3.3 |
| All Assets | 0.5 | 1.7 | 0.5 | 1.8 | 6.4 | 3.5 | - | - |
| ICT | -14.5 | 11.5 | -14.5 | 8.0 | -1.4 | 21.5 | - | - |
| Other Machinery and Equipment | 2.9 | 2.2 | 2.9 | 1.7 | 7.8 | 3.7 | - | - |
| Structures | 1.7 | 0.4 | 1.7 | 1.9 | 8.5 | 2.4 | - | - |
| | | | | 1988-1995 | | | | |
| GDP | - | - | - | - | - | - | 2.4 | 1.5 |
| All Assets | 1.8 | -0.2 | 1.8 | 1.3 | 3.7 | 2.6 | - | - |
| ICT | -8.0 | 13.2 | -8.0 | 11.5 | -2.8 | 17.5 | - | - |
| Other Machinery and Equipment | 2.4 | -2.1 | 2.4 | 1.2 | 2.2 | 1.6 | - | - |
| Structures | 2.0 | -1.9 | 2.0 | 1.3 | 7.2 | 1.6 | - | - |
| | | | | 1995-2000 | | | | |
| GDP | - | - | - | - | - | - | 1.4 | 4.9 |
| All Assets | 0.7 | 11.9 | 0.7 | 3.5 | 1.7 | 4.2 | - | - |
| ICT | -3.2 | 27.6 | -3.2 | 21.3 | 0.3 | 25.1 | - | - |
| Other Machinery and Equipment | 2.0 | 7.7 | 2.0 | 4.1 | 7.5 | 5.5 | - | - |
| Structures | 0.3 | 5.6 | 0.3 | 2.1 | 4.1 | 2.5 | - | - |

## 3. *Growth of Investment, Capital Stock, and Capital Services*

The growth in Canada's use of capital can be traced through an examination of three related data series—an index of the growth in investment, an index of the growth in capital stock (a straight sum of the different assets) and an index of the growth in capital services—from 1981 to 2000. Furthermore, each of these can be decomposed into three components: that arising from investments in ICT, other machinery and equipment, and structures (which include land and inventories).[2]

To better understand aggregate trends, average annual growth rates (in terms of both quantities and prices) are presented in Table 3 for each series for the major asset classes and for the entire period 1981-2000, and for three sub-periods: 1981-1988, 1988-1995, and 1995-2000. Growth rates for business sector GDP for the same periods are also reported.

The dominant feature of these estimates is the significant drop of output growth during the early 1990s recession. After growing around 3.3% per year during 1981-1988, output growth fell to 1.6% per year for 1988-1995 and recovered remarkably during the second half of the 1990's to reach 4.9% per year on average. Investment, capital stock and capital services all show similar growth patterns.

**Investment**

While investment showed a similar growth pattern to growth in output, growth in investment showed more sensitivity to the business cycle. It slowed dramatically from 1.7% per year during 1981-1988 to –0.2% for 1988-1995. However, it surged to 11.9% for 1995-2000, helping to boost GDP growth during this period.

There is substantial variation in the growth rates across asset classes and an accelerating trend toward equipment investment, particularly ICT. Real ICT investment growth was high and rising throughout the last two decades. Despite the GDP slowdown, it was 13.2% per year even during the slow growth in the early 1990s. On the other hand, real investment in non-residential structures and other machinery and equipment dropped to -1.9% and -2.1% per year, respectively, during the period 1988-1995. In recent years, investment in all of the asset classes grew at a much higher pace than during the 1981-1988 period.

The more rapid growth of ICT can be understood by examining the behaviour of relative prices. The rate of inflation of the GDP deflator declined from 4.5% per year (1981-1988) to 2.4% per year (1988-1995) and then to 1.4% per year (1995-2000). The quality-adjusted price of ICT investment goods fell during the same three post-1981 periods (-14.5% to -8.0% to -3.2% per year). Relative to the GDP deflator, ICT prices fell at an average of 12.2% per year over the 1981-2000 period. The other categories of investment experienced price increases, but in general they were still lower than those of the GDP deflator.

[2] See the appendix to Harchaoui and Tarkhani 2002, for the differences between these various concepts.

These investment patterns directly determine the growth of the capital stock. For example, relatively fast ICT equipment investment leads to faster capital stock growth rates and an increase in the capital stock share of equipment.

The long-lived nature of structures, however, means this occurs slowly. The index of real capital stock of ICT equipment, for example, has grown 12.7% per year over the last two decades, while structures grew only 1.7% per year. The share of ICT equipment in the stock of fixed reproducible capital in current dollar terms has increased from 3.9% in 1981 to 6.4% in 2000. This important increase in the value share is due to the large increase in the quantity of ICT capital that more than offset the fall in the price of such capital.

**Capital Formation**

The indices of the growth of Canadian capital stock and capital services show that the post-1995 period has been one of relatively rapid growth in capital stock. The rate of growth of capital fell from 1.8% per year from 1981-1988 to 1.3% per year from 1988-1995 and rebounded sharply to 3.5% per year from 1995-2000. At the asset level, however, while ICT equipment maintained a sustained growth across all periods, both machinery and equipment and structures experienced a significant slowdown during the 1988-1995 period, followed by a marked recovery in recent years.

Trends in the growth of the capital stock are major determinants of the growth of capital services. The growth of capital services is, however, higher than the growth of capital stock, reflecting the ongoing substitution of short-lived equipment for long-lived structures. This shift in composition is sometimes referred to as changes in capital quality—in the sense that it results from changes in composition that are associated with changes in marginal productivity. All else being equal, a short-lived asset has a higher depreciation rate, relatively higher service price and, therefore, a higher relative marginal productivity since competitive markets equate user capital cost to marginal productivity. As a consequence, the fast growing short-lived assets receive a higher weight in the capital service aggregation compared to their weight for the capital stock (see Harchaoui and Tarkhani, 2002). For individual asset classes, the results in Table 3 show that capital-service growth always exceeds the growth of the capital stock, which implies asset substitution also occurs within asset classes.

These data document an important recovery in the growth rate of Canadian capital services across all asset classes in the post-1995 period. This reflects in large part the rapid growth of investment in the second half of the 1990s for all asset classes. This is an important development since it is the growth of capital services and not the level of capital or investment growth that ultimately affects economic growth in output.

As a point of comparison, it is useful to compare these results to the measure of capital services reported for 1999 by the U.S. Bureau of Labor Statistics (BLS) (2000). For the private business sector, which most closely matches our estimates, BLS (2000) reports capital services growth of 3.8% for all assets for 1981-1999, slightly above our estimate of 3.3% for the same period. This may reflect structural differences between the two countries.

For both countries, the trends are quite similar during the various sub-periods. BLS (2000) reports a decrease in the growth of capital services from 3.9% for 1981-1988 to 2.8% for 1988-1995 and then a recovery to 5.3% for 1995-1999 (3.5%, 2.6% and 4.2%, respectively, for Canada). However, there are marked cross-country differences in the growth of capital services at the asset level. The U.S. ICT equipment capital services grew 17.5% during the 1995-1999 period, up from the 14.5% and 8.5% posted, respectively, during the 1981-1988 and 1988-1995 periods. This is far below the performance experienced by its Canadian counterpart (25.7%, 21.5% and 17.5%, respectively). Although in the U.S., other machinery and equipment and structures recovered in the 1995-1999 period in comparison with the 1988-1995 period, this performance remains below that posted in the previous decade. In contrast, during the 1995-1999 period, Canadian other machinery and equipment and structures experienced their fastest growth of the last twenty years.

**Decomposing the Growth in Capital Services**

The previous section showed an increase in the growth of capital services for fixed capital and its asset classes but has neither identified nor quantified the sources of this increase in terms of changes in composition of investment within asset classes and between asset classes. This section does just that. It provides a framework that decomposes the growth in capital services into three major components. In this framework, capital services increase for three reasons—substitution towards short-lived, high marginal product assets within asset classes (within quality effect), substitution between asset classes (between quality effect), and the accumulation of capital stock (capital accumulation effect).

The growth of aggregate capital services (the log represents the growth rate) is decomposable as follows (see Ho, Jorgenson and Stiroh 1999):

$$\ell n\left(\frac{\tilde{K}_t}{\tilde{K}_{t-1}}\right) = \sum_j \overline{v}_t^j \ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) + \sum_j (\overline{v}_t^j - \overline{w}_t^j)\ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right) + \sum_j \overline{w}_t^j \ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right). \qquad (1)$$

where $\tilde{K}_t$, $\Delta_t^j$, $\bar{K}_t^j$ represent, respectively, aggregate capital services, quality change of the asset class $j$ = ICT, other machinery and structures and the capital stock of the asset class $j$ at period $t$; $\overline{v}_t^j$ and $\overline{w}_t^j$ are, respectively, average rental cost share and average value share of capital stock for the asset class $j$ at period $t$.

Each of these three components has a specific economic interpretation. The first term on the right-hand side will be referred to as the "within quality effect," which measures substitution and capital quality growth within distinct asset classes. The second term represents the "between quality effect," which measures substitution between distinct asset classes. The last term is the "capital accumulation effect," which measures capital stock accumulation.

Table 4 presents the contribution to the growth in total fixed capital services from each component for 1981-2000 and sub-periods. The decomposition allows us to identify the sources of increase of capital services growth by comparing each component across asset classes and over time. Table 4 should be read in the following manner. Consider the 3.4% per year growth of capital services for the 1981-2000 period (last column, first row). This is made up of a 1.2%

contribution from ICT, 0.8% from other machinery and equipment and 1.4% from structures. Looked at from the decomposition outlined in equation 1, this 3.4% comes from 0.9% of a within-class effect (substitution across assets within an asset class), 0.3% from a between-class effect (substitution across asset classes), and 2.1% of a capital-accumulation effect (general growth across all asset classes).

**Table 4. Decomposition of the Growth in Capital Services by Asset Class: Canadian Business Sector**
(annual average growth rates)

| | Within Quality Effect | Between Quality Effect | Weighted Capital Accumulation | Capital Services Growth |
|---|---|---|---|---|
| | | 1981-2000 | | |
| ***Fixed Capital*** | **0.9** | **0.3** | **2.1** | **3.4** |
| Information and Communication Technology | 0.4 | 0.3 | 0.5 | 1.2 |
| Other Machinery and Equipment | 0.3 | 0.1 | 0.4 | 0.8 |
| Structures | 0.2 | -0.1 | 1.2 | 1.4 |
| | | 1981-1988 | | |
| ***Fixed Capital*** | **1.4** | **0.1** | **2.0** | **3.5** |
| Information and Communication Technology | 0.6 | 0.2 | 0.2 | 1.0 |
| Other Machinery and Equipment | 0.5 | 0.1 | 0.3 | 0.9 |
| Structures | 0.3 | -0.1 | 1.4 | 1.6 |
| | | 1988-1995 | | |
| ***Fixed Capital*** | **0.7** | **0.3** | **1.7** | **2.6** |
| Information and Communication Technology | 0.4 | 0.3 | 0.4 | 1.1 |
| Other Machinery and Equipment | 0.1 | 0.1 | 0.3 | 0.4 |
| Structures | 0.2 | -0.1 | 1.0 | 1.1 |
| | | 1995-2000 | | |
| ***Fixed Capital*** | **0.7** | **0.6** | **2.9** | **4.2** |
| Information and Communication Technology | 0.2 | 0.6 | 0.8 | 1.6 |
| Other Machinery and Equipment | 0.3 | 0.1 | 0.8 | 1.2 |
| Structures | 0.2 | -0.1 | 1.3 | 1.4 |

The estimates show that at the aggregate level the capital-accumulation effect is the primary source behind the growth of total capital services for all periods. However, this varies across asset classes: the total quality effect (the sum of the within and between quality effect) constitutes the major source behind the growth of ICT capital services for all periods, while the capital-accumulation effect tends to dominate for other machinery and equipment and structures. Substitution across asset groups within an asset class becomes increasingly important over time, particularly for ICT.

For all periods and all asset classes, the total quality effect is primarily driven by the within quality effect. However, the 0.7 percentage point annual increase of capital services between 1981-1988 and 1995-2000, which is mainly attributable to ICT and other machinery and equipment, is mostly driven by the between-effect and the capital-accumulation effect, which increased by 0.5 and 0.9 percentage points per year, respectively.

# *III. Sources of Economic Growth*

## *1. Framework*

The growth of capital services along with the growth in labour input and multifactor productivity are the three primary determinants of the economic growth in output. The final part of this paper evaluates the relative importance of these sources of Canadian economic growth during the period 1981-2000.

This type of growth accounting exercise has a rich history beginning with the seminal work of Solow (1957), who integrated the aggregate production function with national income data to produce an estimate of productivity growth that captured disembodied technical change. Aggregate output $Y_t$ is considered to be produced from capital services $\tilde{K}_t$ and labour services $\tilde{L}_t$. Representing productivity as a 'Hicks-neutral' augmentation $A_t$ of aggregate input, output can be written as:

$$Y_t = A_t F\left(\tilde{K}_t, \tilde{L}_t\right) \tag{2}$$

Under the assumptions of competitive product and factor markets, and constant returns to scale, growth accounting gives the growth of output as the sum of the share-weighted growth of inputs and growth in multifactor productivity:

$$\Delta \ell n Y_t = \overline{s}_{K,t} \Delta \ell n \tilde{K}_t + \overline{s}_{L,t} \Delta \ell n \tilde{L}_t + \Delta \ell n A_t \tag{3}$$

where $\overline{s}_{K,t}$ and $\overline{s}_{L,t}$ are respectively, capital's and labour average share of nominal value-added, $\overline{s}_{K,t} + \overline{s}_{L,t} = 1$, the augmentation factor $A_t$ captures multifactor productivity and $\Delta$ refers to a first difference.

Equation (3) has several attractive features. It facilitates the decomposition of the growth in output into the contributions made by labour and capital inputs on one hand, and a residual that is called multifactor productivity growth, on the other hand. It also allows for the quantification of the contributions of different types of capital, such as ICT, to the growth of output.

In addition, rearranging equation (3) enables us to present results in terms of labour productivity growth

$$\Delta \ell n\left(\frac{Y_t}{H_t}\right) = \overline{s}_{K,t} \Delta \ell n\left(\frac{\tilde{K}_t}{H_t}\right) + \overline{s}_{L,t}\left(\Delta \ell n \tilde{L}_t - \Delta \ell n H_t\right) + \Delta \ell n A_t \tag{4}$$

where $\frac{Y_t}{H_t}$ and $\frac{\tilde{K}_t}{H_t}$ are, respectively, output per hour worked and the ratio of capital services to hours worked. This gives the familiar formula that allocates labour productivity growth among three factors. The first is *capital deepening*, the growth in capital services per hour. Capital deepening (also called *capital intensity*) makes workers more productive by providing more capital for each hour of work and raises the growth of labour productivity in proportion to the share of capital. The second term is the improvement in labour quality, defined as the difference between the weighted growth rates of each category of labour and the growth in the simple sum of hours worked across all worker categories. Reflecting the rising proportion of hours supplied

by workers with higher marginal products, labour quality improvement (also called the *labour composition effect*) raises average labour productivity growth in proportion to labour's share. The third term is *multifactor productivity* growth, which increases labour productivity growth on a point-for-point basis. Long-term labour productivity growth arises from three sources: multifactor productivity growth, the contribution of increased capital intensity, and the contribution of shifts in labour composition.

As shown in equation (4), labour productivity (output per hour) can differ from multifactor productivity (output per unit of combined capital and labour inputs) if capital deepening occurs or if labour quality improves.

The remainder of this section provides empirical estimates of the variables in equations (2) through (4). Equations (3) and (4) are then employed to quantify the sources of growth of output and average labour productivity for 1981-2000 and various sub-periods.

## *2. Empirical Results*

This section provides the results associated with equations (3) and (4) which provide two different, but related, perspectives on the sources of growth: the latter decomposes the sources of labour productivity growth and the former identifies the sources of economic growth of total output. The section commences with an examination of the sources of labour productivity growth.

**The Sources of Labour Productivity Growth**

The contribution of capital intensity to labour productivity growth equals the growth in the capital-hours ratio multiplied by capital's share of nominal value-added. The contribution of labour composition equals the difference between the growth rates of labour input and of hours worked multiplied by labour's share of nominal value-added. Historically, capital's share has been slightly more than one-third of nominal value-added in the business sector.

Table 5 indicates that from 1981 to 2000, labour productivity grew at an annual rate of 1.4% in the business sector. Of the 1.4% growth in labour productivity, 0.3% can be attributed to increases in multifactor productivity, 0.6% to the contribution of capital intensity, and 0.5% to changes in labour composition. Table 5 displays a moderate labour productivity increase during the 1980s and early 1990s, and an acceleration of labour productivity growth in the late 1990s. This acceleration reflects the remarkable pick-up in multifactor productivity growth in recent years.

During 1988 to 1995, multifactor productivity decreased -0.3% per year in the business sector. At the same time, the average annual contribution of capital intensity to labour productivity growth increased to 0.9%, and labour composition made a 0.6 percentage point contribution. Labour productivity, therefore, increased 1.2% per year from 1988 to 1995. ICT capital began to play an increasingly important role during this period, contributing 0.4% per year, or more than two-fifths of the contribution of capital deepening to labour productivity growth.

**Table 5. Annual Average Percentage Point Contribution to Labour Productivity*: Canadian Business Sector**

| | 1981-2000 | 1981-1988 | 1988-1995 | 1995-2000 |
|---|---|---|---|---|
| Labour Productivity Growth (annual average growth rate) | 1.4 | 1.3 | 1.2 | 1.7 |
| Capital Deepening | 0.6 | 0.6 | 0.9 | 0.4 |
| Information and Communication Technology | 0.4 | 0.3 | 0.4 | 0.4 |
| Other Machinery and Equipment | 0.1 | 0.1 | 0.1 | 0.1 |
| Structures | 0.1 | 0.1 | 0.3 | -0.1 |
| Labour Quality | 0.5 | 0.5 | 0.6 | 0.3 |
| Multifactor Productivity (annual average growth rate) | 0.2 | 0.2 | -0.3 | 1.0 |

*Except where noted

During 1995-2000, labour productivity grew 1.7% per year in the business sector, 0.4 percentage points faster than during the 1988-95 period. This acceleration is attributed entirely to the remarkable resurgence of multifactor productivity growth, which increased by more than one percentage point. Continuing the trend in substitution of ICT for other forms of capital, ICT capital accounted for the whole contribution of capital deepening to labour productivity growth. Growth in labour quality slowed relative to the growth in hours in the 1995-2000 period.

**The Sources of Economic Growth**

Using the framework developed above, the capital and labour inputs are combined with output data to estimate the components of equation (3) to quantify the sources of economic growth in output from 1981-2000. In addition to the standard contribution of aggregate capital services, the analysis also examines the contribution of each broad asset class to total growth.

Results are reported in Table 6 and should be read in the following manner. In the second column, for the period 1981-1988, output grew at 3.3% per year, of which aggregate capital services contributed 1.4%, labour input 1.7%, and multifactor productivity 0.2%. The 1.4% capital contribution is from the growth rate of capital services multiplied by the $\overline{s}_{K,t}$ share and may also be decomposed into a 0.8% contribution of capital accumulation and 0.6% of quality change. Similarly, the 1.7% labour input contribution can be decomposed into a 1.2% contribution from increased hours worked and a 0.5% contribution from quality change due to substitution toward more highly educated workers.

For 1995-2000, output grew 4.9% per year, capital services contributed 1.7 percentage points, labour input contributed 2.2 percentage points, and multifactor productivity contributed 1.0 percentage points.

As reported above, there has been an increase in the contribution of capital services during 1995-2000 as the growth contribution increased to 1.7% from 1.4% per year over 1981-1988. ICT shows the largest increase in the contribution of capital services between the two periods, nearly doubling from 0.4% to 0.7%. In addition, the most recent estimates show an increase in the growth of multifactor productivity that is above any rate since 1981.

**Table 6. Sources of Economic Growth: Canadian Business Sector**
(annual average percentage point contribution) *

| | 1981-2000 | 1981-1988 | 1988-1995 | 1995-2000 |
|---|---|---|---|---|
| Output Growth (annual average growth rate) | 3.0 | 3.3 | 1.5 | 4.9 |
| Contribution of Capital Services | 1.3 | 1.4 | 1.0 | 1.7 |
| Information Communication Technology | 0.5 | 0.4 | 0.4 | 0.7 |
| Other Machinery and Equipment | 0.3 | 0.4 | 0.2 | 0.5 |
| Structures | 0.5 | 0.6 | 0.4 | 0.5 |
| Contribution of Labour Input | 1.5 | 1.7 | 0.8 | 2.2 |
| Multifactor Productivity (annual average growth rate) | 0.2 | 0.2 | -0.3 | 1.0 |
| | | | | |
| Contribution of Capital Stock | 0.9 | 0.8 | 0.6 | 1.4 |
| Contribution of Capital Quality | 0.5 | 0.6 | 0.4 | 0.3 |
| Contribution of Labour Hours | 1.0 | 1.2 | 0.1 | 1.9 |
| Contribution of Labour Quality | 0.5 | 0.5 | 0.6 | 0.3 |

* Except where noted

## Canada-U.S. Comparison of Multifactor Productivity Growth

An examination of Table 7 for both the Canadian and U.S. business sectors over 1981-1999, the most recent period for which U.S. multifactor productivity estimates are available, reveals that Canada's multifactor productivity grew at 0.2% per year on average, compared to 0.9% per year for the U.S. This productivity gap between the two countries is largely attributable to Canada's relatively modest multifactor productivity performance from 1981 to 1995. The lack of multifactor productivity gain in Canada from 1981 to 1995 (0.0% compared with 0.7% in the U.S.) reflects a 2.4% increase in output (3.3% in the U.S.) and a 2.4% increase in combined inputs of capital and labour (2.5% in the U.S.).

In the late 1990s, output grew at an average annual rate of 4.8% in Canada (4.9% for the U.S.), a 3.2 percentage point increase relative to the early 1990s (2.7 percentage points for the U.S.). Multifactor productivity growth makes an important recovery to 1.0% in Canada (1.3% for the U.S. as well), while capital services' contribution to growth recovered to 1.7% in Canada (1.8% in the U.S.), and labour's contribution rebounded to 2.1% points (1.8% for the U.S.).

Multifactor productivity growth is the source of 21% of output growth in Canada (27% in the U.S.), up from 6.1% in the 1981-1988 period (26% for the U.S.). The acceleration in multifactor productivity growth in Canada and the U.S. is perhaps the most remarkable feature of the data. Its acceleration in Canada from -0.3% per year to 1.0% per year (0.5% to 1.3% in the U.S.) between 1988-1995 and 1995-1999 suggests considerable improvements in technology and increases in the efficiency of production. While the resurgence in multifactor productivity growth in the post-1995 period has yet to surpass the pre-1973 performance, more rapid multifactor productivity growth occurred in the last part of the 1990s.

**Table 7. The Sources of Economic Growth Canada and U.S., Business Sector**
(annual average percentage point contribution)*

| | Canada | U.S. | Canada | U.S. | Canada | U.S. | Canada | U.S. |
|---|---|---|---|---|---|---|---|---|
| | 1981-1999 | | 1981-1988 | | 1988-1995 | | 1995-1999 | |
| Output (annual average growth rate) | 2.9 | 3.6 | 3.3 | 3.9 | 1.5 | 2.2 | 4.8 | 4.9 |
| Contribution of Labour Input | 1.4 | 1.5 | 1.7 | 1.6 | 0.8 | 0.9 | 2.1 | 1.8 |
| Contribution of Capital Services | 1.3 | 1.2 | 1.4 | 1.3 | 1.0 | 0.8 | 1.7 | 1.8 |
| Contribution of ICT | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.3 | 0.7 | 1.1 |
| Contribution of Other Machinery and Equipment | 0.3 | 0.3 | 0.4 | 0.4 | 0.2 | 0.2 | 0.5 | 0.4 |
| Contribution of Structures | 0.5 | 0.4 | 0.6 | 0.4 | 0.4 | 0.2 | 0.6 | 0.4 |
| Multifactor Productivity (annual average growth rate) | 0.2 | 0.9 | 0.2 | 1.0 | -0.3 | 0.5 | 1.0 | 1.3 |

*Except where noted

U.S. data are taken from the U.S. Bureau of Labor Statistics (2000).
Numbers may not add due to rounding.

## *IV. Conclusion*

This paper has documented the evolution of the sources of economic growth of the Canadian business sector. The major finding is the growth in output of the Canadian business sector in the post-1995 period has been substantially above the earlier part of the decade and of the previous decade. In addition, after almost two decades of lacklustre performance, the productivity statistics, beginning in 1995, have begun to reveal the impact of increasing capital formation in ICT technologies. Progress in ICT is driving down relative prices of computers, software, and communication equipment and inducing investment in these assets by firms (12.2% per year growth on average during the 1981-2000 period).

The paper also examines the pattern of growth in capital services in terms of both quantity and quality components. It distinguishes between capital quantity growth due to investment, and capital quality growth due to substitution between different types of capital assets. Much of the recent investment boom has been associated with substitution across assets as the relative price of high-tech assets steadily fell. Capital 'quality' grew over the 1981-2000 period at 1.2% per year on average, of which 75% was due to changes within asset classes.

In terms of the sources of the 3.3% annual average growth over the 1981-1988 period, capital input contributed 1.4% per year (0.6% for quality and 0.8% for capital quantity), labour input contributed 1.7% per year (1.2% for hours and 0.5% for labour quality). This is somewhat similar to the 1995-2000 period, when capital input at 1.7% contributed less than labour input at 2.2% per year to output growth.

In both countries, ICT is the largest contributor to growth within capital services, during the late 1990s, followed closely by structures in Canada. But the contribution of ICT in Canada is lower than in the U.S.

What is even more remarkable about the post-1995 period, compared to the previous periods, is the recovery in the multifactor productivity performance, posted at 1.0% per year in Canada and 1.3% in the U.S. (compared to 0.2% and 1.0%, respectively, for the 1981-1988 period).

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